Data representation for the control of full-automated microfactories

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***Abstract* – The increase greater than ever in the developments of microproducts leads us to consider the design of an automatic, flexible, reconfigurable and upgradeable microfactory. Thus defined, the microfactory has the ability to implement an infrastructure of automated manufacture in small or average batches, and will be able to prove the feasibility of automated production in greater quantity.**

Two main difficulties have been identified. First, the operator in charge of the production setting has accessibility problem in the microworld. Second, the permanent adaptation of the production system to the variations of the intrinsic parameters of the microworld.

Consequently, such a concept of microfactory must assist the operator by the capitalization of last experiments and the restitution of acquired know-how.

Taking into account the importance and diversity of information, our approach consists in defining all this technical information system. Our method went on a modeling of the microfactory under UML, using the "use-cases" and "classes" diagrams.

The technical information system resulting from our work is the spinal cord of the microfactory, it will constitute the base of the piloting structure.

Index Terms* - *microfactory architecture, control system, technical information system, Manufacturing Execution System, Unified Modelling Language

I. Introduction

The existing production systems don't allow to treat the microproducts. The specific characteristics of the microworld are unusual for the human ones which evolve in a world with their size, that we call in this article "the mesoworld", we were brought to think of an adapted "system of production of microproducts".

Since one wishes to produce on the micro scale, the difficulties of accessibility arise because, dexterity does not make it possible to act with precision, and, our senses do not enable us to feel the sizes of the microworld directly.

A second difficulty specific to the production in quantity on this scale relates to the reliability of the selected process because the phenomena and the efforts brought into play are unusual for us, human. Thus, the production of microproducts shows an indeterminist character.

Our approach of the microfactory concept must allow an implementation on a broad domain which we present, after having established an inventory of specificities of the microworld.

Next, we describe the domain of application of our approach of the microfactory, and its working principle. From that, because a micro technical information system is different from a meso technical information system, we extract the data characteristic of technical information system. It is about the initial stage essential to the structuring of the mass of information operating dynamically in a microfactory [1].

We comment on then, starting from especially developed UML models, the microfactory structure which we set up to answer such a schedule of conditions.

Lastly, we locate the continuation of our work and the prospects for evolution.

II. Specificities of the microworld

The conventional production systems of the mesoworld are generally deterministic insofar as the production environment and the physical behavior of the production and process are under control.

On the contrary, in the microworld, the determinism is not verify because, taking into account the problems of accessibility and of direct handling, we have no experimental human being at this scale and the system must face to unexpected and unusual risks. The physical laws of the microworld are known [2] but the whole of the parameters which interact is not easily controlled. And even if we would be able to determine and control all these parameters, the simulation of the behavior would take to much time to be implemented on the current multi-physics software.

On this subject, the main cause of this practical indeterminism is related to the inversion of the ratio of the volume forces compared to the surface forces. Indeed, whereas the mechanical actions of the mesoworld are mainly due to magnetism, gravity, Archimedes, the mass or the inertia moment, when we enter in the microworld, the actions of the electrostatic forces, of the surface stresses, the forces of Van der Waals, the force of adhesion (pull-off), of fluid frictions become influential and most of the prominent.

Consequently, all the know-how acquired by the engineers in the mesoworld is not directly transposable in the microworld. The principal reason is explained by the scale factor which intervenes to the power of two or to the power of three according to whether they are surface or volume forces. Therefore, with the scaling, the interactions introduce infinitely small order two or three. Thus, the effects of the volume forces tend to become negligible or equivalent to the effects of the surface forces which are usually neglected in the mesoworld. As example, we can quote some specificities of physical laws which are the more interesting for micromanipulation:

- Great possible accelerations of the microparts because low volume generates a low mass and a weak inertia, therefore a micropart can undergo great variations of movement.
- Weak push of Archimedes independently of material (because low volume makes the density negligible), from where the possibility of intervention in liquid surroundings.
- The absence of electrostatic effort and surface stress in liquid surroundings (aqueous), which is pertinent for microhandling in a liquid.
- On the contrary, great dependence with the dynamics of the fluids in contact (current or movement in a gas or a liquid), which who avoid the loss of parts.
- Dependence with the remote actions of electrostatic type (because the charges accumulate on surfaces, edges, points), therefore a strong sensitivity to the geometry.

In addition, it is important to note that the level of "direct intervention" of an operator is quite reduced because the micrometric systems are essentially out of reach to the operator for the reason that his limits of sensory and muscular capacities. Moreover, natural uncontrolled movements, due to humain being, limit the precision and the resolution of the direct human action. Fragile microsystem could be destroyed. Perceptions and actions are necessary supported by safety interfaces.

III. Applicability concerns

Our approach of the production relates to the assembly of microcomponents as well as the manufacture of a microproduct.

To avoid any confusion, we make a point of specifying the used vocabulary:

The matter of entering work, in transit or outgoing is called either a "microcomponent" (in entry or in a unit of a intermediary part), or a "microproduct" (in outgoing).

The object of our study relates to microfactories able to produce successively various types of microproducts into small or average quantity, for which the development and the installation of a production dedicated line are not financially profitable. For this reason, we work with a modular, flexible and evolutionary architecture which make it possible to have a re-configurable and re-organizable production equipment [3].

Thus, the organization of a platform of production of microproducts can make profitable the small size of production cells easily removable and easy to handle, and with a moderate cost. We call "cell" the "smaller autonomous entity in the production system". We define the size of a cell such that it holds in a volume of approximately a decimeter cubic and the function of a cell such as it carries out at least a task of production. We can observe that in the mesoworld the flows of products are adapted to the machines installation of the manufacture workshop. On the contrary, on micrometric scale, we have a flexibility of intervention on the organization of the flows of products. In fact, and it is an additional interest there, on the relative organization of the cells between them, without having to consider the important and expensive works of substructure or even of civil engineering.

Another important aspect in the development of the concept of microfactory relates to the progressive integration of know-how and the capitalization of knowledge specific to the microworld. Finally, implementation of microproduction system is more and more fast and also the design of the micro product.

IV. Working principle

The main objective to reach is to provide a production process automated to 100%. We don't seek to develop a microfactory able to treat a mass production for which there are powerful systems of production, but we minks to allow a production of small and average series of several microproducts in batches. Several productions are not superimposed during the same temporal period, but they are connected successively on the same "PlatForm of the Production of the Microproducts" (see def. PFPM in § V). For this reason, the operative part, but also the control part must be re-organizable to pass from a production to another one. Because the operative and control resources brought into play are different from one production to another, we base our approach on a flexible system and modular subsystems [3].

Thus, since the production of some batches of a microproduct was stabilized in automatic functioning, a Production Platform can be dedicated to manufacture the microproduct in biggest series. We differentiate such productions insofar as a big series is defined such as its important duration of production imposes the use of a dedicated equipment.

To achieve the automation of the process, we backed flat the process in progress, and, if necessary, to reconfigure the Platform of Production of microproducts. This approach leads to a very dynamic technical information system ready to use tools of representation, filing, handling, exploitation, and communication of information.

During the development of a process, it is necessary to accede to the cells resources to try out the tasks of the assembly or manufacturing ranges. But also in the course of production, as long as the process is not made reliable, it must be possible to modify the structure or the parameter setting of the operative elements; it is about reconfiguration. That is only possible thanks to a system of supervision which is functioning because of alarms and indicators of production, and which allows, in real time or by the call of former recordings, the access to the production data by the operator or by the system of organization. With such a follow-up of the production, it's possible for the system of organization to be very reactive to the uncertainties. Thus, that is possible to make reliable the automated process by reconfiguring with the modification of the resources equipment or of the parameter setting.

All the data of production and the blaming of the process will be necessary to sort and capitalize in order to extract some know-how in the microfactory or more specifically in a cell.

For example, the modeling of the various cases of uses for the operator who organizes the production was made by an UML representation (Figure 1).

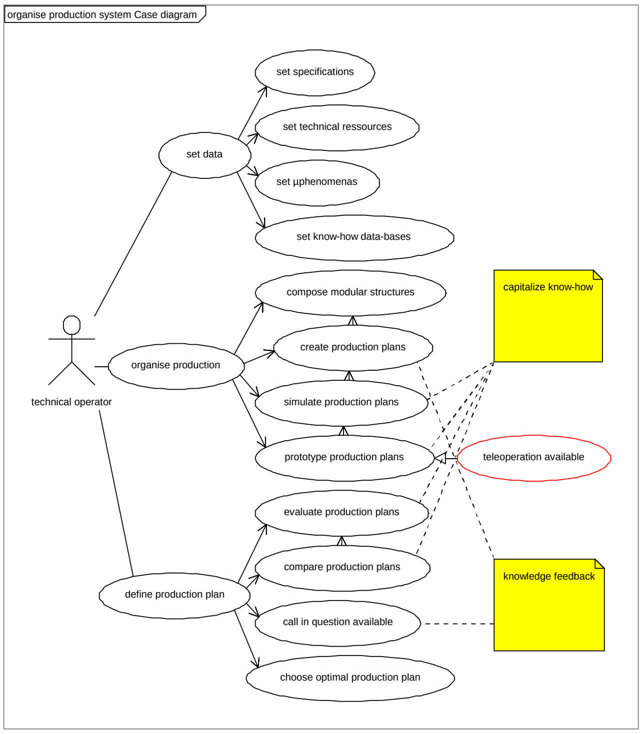

Figure 1, UML case diagram for organize production system

This thought process is mainly run on the level of the MES activity (Manufacturing Execution Systems) of the technical information system of the decision model of the CIM pyramid (Computer Integrated Manufacturing, Figure 2, [4], [5]). The level of "operating system" is also concerned because it is where the microworld is located.

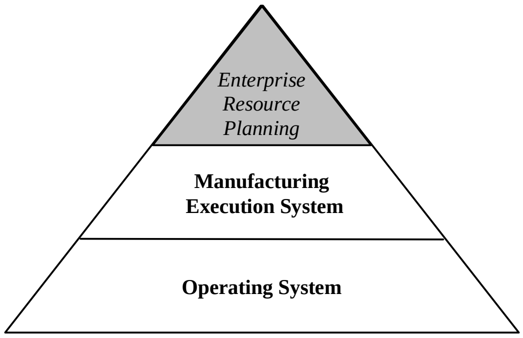

Figure 2, positioning in CIM model

Among the eleven functions of the MES system indexed by the ISA-95 [6] (Figure 3), five are less concerned with our framework of application, we only study the six described below:

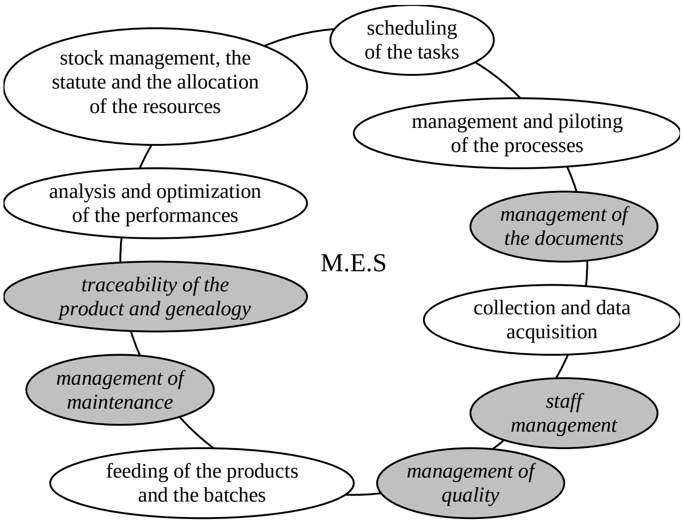

Figure 3, eleven MES functions of the ISA-95

- The "scheduling of the tasks" (the implementation of the manufactoring process, i.e. its design); it will be initially given according to the known and listed data. Then it will evolve and called into question permanently, making evolutionary the process of generation.

- The “management and piloting of the processes”; their validation by simulation and the experimentation by remote-control in manual mode, the actualization of ranges, the traceability and the filing of the processes, are as many evolutions of the technical information system specific of the microworld.

- “Collection and data acquisition”; on the one hand, it is the only possibility of information of the operator about the state of the microworld, on the other hand, they will allow the capitalization of know-how.

- The “feeding of the products and the batches”; transfers between the cells, inside of a cell, and the supply of raw material are important because of the microcomponents size.

- “Analysis and optimization of the performances”; this function is the major aspect of reconfiguration thanks to the installation of indicators, and with capitalized knowledge.

- “Stock management, the statute and the allocation of the resources”; the material development of cells and modular elements, their evolution, the specialization of each cell make this function specific for the systems of production of microproducts.

V. Our structure of operating system

Our concept of microfactory is based on the construction of cells of production. Each “basic cell” is the subject of thorough design engineering and research [7]. It has micro-actuators and/or microsensors arranged between-them in a precise way to allow specific functionalities. The cell comprises parameters of inputs and outputs naturally accessible from the organization system and the operator. As far as possible, modeling of the behavior of the cell is provided with the cell in particular to allow its simulation. The models are enrich progressively with the acquisition of new knowledge resulting from the use of the cell.

In addition, such a basic cell if needed will be modified by the addition of active elements and/or passive elements. We define a “active element” as a body having input(s)-ouput(s) (example: sensor, or actuator), and a “passive element” as a body not having input-output (a simple tool). This modularity obtained by active or passive elements is illustrated under UML by the following diagrams (Figure 4).

Each cell used for the implementation of a task of the assembly plan is initially the subject of a simulation and/or an experimentation in order to validate its parameter setting.

After the validation of the use of various cells, the initial organization of the production is defined while being based on multiple criteria coming from the specifications of the production.

The organization of the obtained cells form the Platform of the Production of the Microproducts (abbreviation PFPM). Contrary to the often linear lines of production of the meso-world, the PFPM can be spread while following two dimensions (organization in matrix, triangular, circular, etc), or even in three dimensions (organization cubic, spherical, cylindrical, conical, pyramidal, by layers, etc).

The architecture of the PFPM is articulated around three standard bodies of connection being used as interface of communication, energy, products. Three flows corresponding are based, according to cases, on a material or immaterial support.

If need be, the PFPM has a specific environment (clean room, antivibratory enclosure, fluid environment, black room, etc).

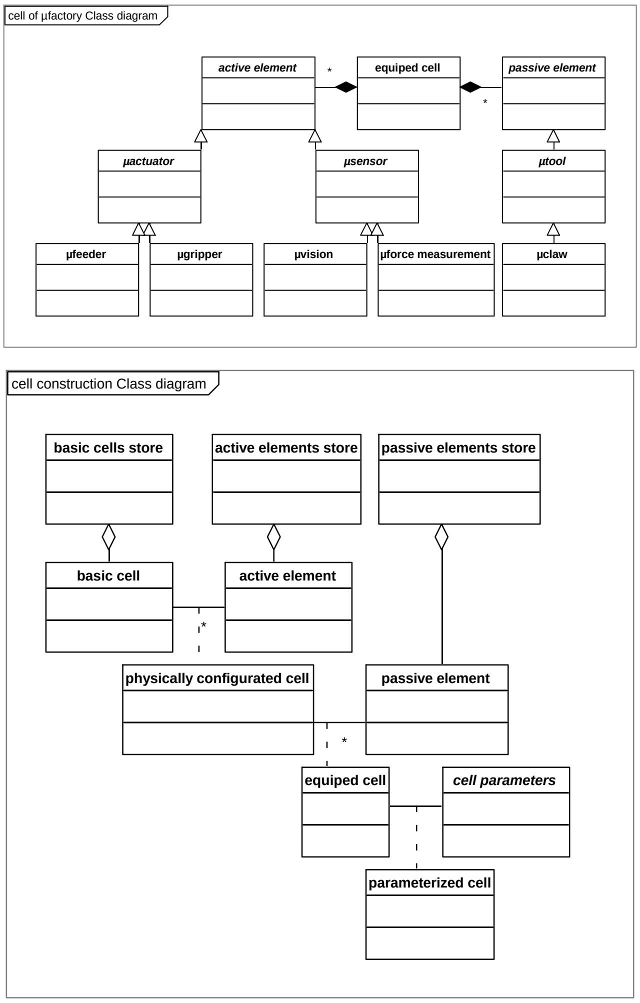

Figure 4, microfactory's cells diagrams

Lastly, the definition of an advanced “human machine interface” must amongst other things make it possible to make available the microworld to the operator for the observation, or the remote-control.

VI. Conclusion, outlines

A automated and reconfigurable microfactory must be built on a considered architecture of its technical information system. Forming its “spinal cord” brain”, we worked to identify specificities of the intervening data. For that the identification of the MES concerned functions, and the use of UML as a tool for dialogue are two initiating stages for the definition of the schedule of conditions of an objects programming of an adapted Software package.

We also highlighted the interest of the capitalization of knowledge for, on the one hand, the reconfiguration of a cell or of the PFPM, but also to allow, on the other hand, the redesign of microproducts manufactured in automated microfactory. We think that this approach would lead to new kind of cells, and also of new methods of design and development of microproducts.

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